the apparatus required, then treats of the Algæ as a class, and the main divisions into which they have been separated by botanists, and in most of the remaining part of the book describes species, "choosing as types of each genus such species as are most likely to be met with, and leaving out those which are either rare or possess few points of interest for the beginner." Mr. Smithson himself points out that the volume leaves much to be sought elsewhere; but, if used intelligently, it will do sound work by preparing the way for wider study.

Rambles and Reveries of a Naturalist. By the Rev. William Spiers, M.A., F.G.S., &c. (London: Charles H. Kelly, 1890.)

MR. SPIERS does not profess to give in this little book a full account of any one of the subjects with which he deals. His aim has been "to awaken or to stimulate a love for Nature in the minds of some who may not as yet have suspected what wondrous and ever-varying beauty lies everywhere about us, in ditch and pond, in rock and stone, in river and sea, on earth and in the skies." With this end in view, he describes, in a series of short sketches, various phenomena which he himself has had opportunities of observing; and he does his work so well that to a good many readers his book may be of considerable service. There is nothing new or brilliant in Mr. Spiers's descriptions; but they are fresh and clear, and display not only a genuine love for Nature, but a capacity for appreciating the scientific significance of many different orders of facts. Besides other essays, the volume includes papers on seaweeds, rambles in Cornwall, a visit to the Channel Tunnel, St. Hilda's snake-stones, tiny rock-builders, and an evening at the microscope.

Sketches of British Sporting Fishes. By John Watson. (London: Chapman and Hall, 1890.)

A PREFATORY note to the "Sketches" tells us that "the subject-matter has, for the most part, been gleaned directly from the waterside, and should be looked upon more as the notes of a naturalist than the jottings of an angler." Accordingly, it was with anticipation of interest that we turned to the opening chapter, on salmon.

So little is known of the natural history of the salmon, and so great is its value, both for sport and for food, that we eagerly scan the pages of a naturalist and an angler who may tell us what he has seen and knows. Mr. Watson has nothing to tell us. He disposes of the salmon in 12 pages, and the impression produced upon us is that his acquaintance with that noble fish is confined to the fishmonger's slab, and to the dinner-table.

The chapter on trout is little more satisfactory. That on grayling is by another hand.

LETTERS TO THE EDITOR.

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Coral Reefs, Fossil and Recent.

DR. VON LENDENFELD has (June 12, p. 148) quoted cases to contest my statement that there are no coral reefs whose slopes are known to descend steeply to greater depths than about 4000 feet. I must take these seriatim.

(1) "Fitzroy's no-bottom sounding of 7200 feet at a distance of 6600 feet from the breakers at Keeling Island."

I hope I shall not be misunderstood when I say that I cannot accept this as conclusive evidence. Experience daily shows us how little confidence can be placed in a single deep sounding, taken before the days of suitable apparatus, and with no description of the means employed, either to fix the position exactly, or to obtain the cast. It may be correct, but on the other hand it may not be.

(2) "Maldives, &c., rise from a bank of 1000 fathoms very abruptly."

I cannot find any deep soundings near these groups at all. One sounding of 1243 fathoms at a distance of 10 miles is the closest.

(3) "Bermudas rise abruptly out of a depth of 12,000 to 13,000 feet."

There is only one sounding of 12,000 feet anywhere near Bermuda, and as that is six miles from the nearest shallow water, the isolated Challenger Bank, it represents a slope of only 19°.

In point of fact, very few slopes of coral formations have yet been accurately measured. Among the most remarkable that I know are:—

Bougainville Reef in Coral Sea, which drops perpendicularly from the water-level to 360 feet; at a mean slope of 76° to 780 feet; and at 53° to 1500 feet.

Dart Reef, in same sea, has a mean slope of 64° to 1200 feet.

Macclesfield Bank, a so-called, "drowned" atoll, in China Sea, has a mean slope of 51° to 4200 feet, and possibly more.

The existing conditions of the steep outer slopes of atolls are sufficiently astonishing. All I wish to maintain is that we should argue upon proven facts, and not assumptions, which tend to exaggerate difficulties, and to lead us astray.

With regard to Dr. von Lendenfeld's explanation of the limitation of depths of lagoons, I must await a better before I am convinced. My point is that it is very remarkable that no matter how vast the lagoon, and how deep the steep outer slopes, no lagoon has more than a certain depth, and that such a limited depth that isolated coral heads can spring out of it; and I cannot make this general fact fit with a general theory of subsidence, even when varied by occasional elevations.

The "drowned" atolls are no deeper than others whose rims are at the surface; *vide* Great Chagos Bank, and Suadiva Atoll in Maldives.

W. J. L. WHARTON.

June 14.

ELECTRO-MAGNETIC RADIATION.[1]

IN order to discover whether actions are propagated in time or instantaneously, we may employ the principle of interference to measure the wave-length of a periodic disturbance, and determine whether it is finite or no. This is the principle employed by Hertz to prove experimentally Maxwell's theory as to the rate of propagation of electro-magnetic waves. In order to confine the experiments within reasonable limits we require short waves, of a few metres' length at most. As the highest audible note gives waves of five or six miles long, and our eyes are sensitive only to unmanageably short waves, it is necessary to generate and observe waves whose frequency is intermediate between them, of some hundred million vibrations per second or so. For this purpose we may use a pair of conducting surfaces connected by a shorter or longer wire, in which is interposed a spark-gap of some few millimetres' length. When the conductors are charged by a coil or electrical machine to a sufficiently high difference of potential for a spark to be formed between them, they discharge in a series of oscillations, whose period for systems of similar shape is inversely proportional to the linear dimensions of the system so long as the surrounding medium is unaltered. When the surrounding non-conducting medium changes, the period depends on the electric and magnetic specific inductive capacities of this medium. Two such systems were shown: a large one, whose frequency was about 60 millions per second; and a small one, whose frequency was about 500 millions per second. The large one consisted of two flat plates, about 30 cm. square and 60 cm. apart, and arranged in the same way as is described by Prof. Hertz in *Wiedemann's Annalen*, April 1888. The smaller vibrating system consisted of two short brass cylinders terminating in gilt brass balls of the same size, and arranged in the same way as the smaller system described by Prof. Hertz in *Wiedemann's Annalen*, March 1889. This latter system was placed in the focal line of a cylindrical parabolic mirror of thin zinc plate, such as that described by Prof. Hertz in this paper.

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[1] Friday Evening Lecture delivered at the Royal Institution, on March 21, by Prof. G. F. Fitzgerald, F.R.S.

These generators of electro-magnetic oscillations may be called electric oscillators, as the electric charge oscillates from end to end. A circle of wire, or a coil in which an alternating current ran, or, if such a thing were attainable, a magnet alternating in polarity, might be called a magnetic oscillator. A ring magnet with a closed magnetic circuit is essentially an electric oscillator, while a ring of ring magnets would be essentially a magnetic oscillator again. The elementary theory of a magnetic oscillator can be derived from that of an electric oscillator by simply interchanging electric and magnetic force. Electricity and magnetism would be essentially interchangeable if such a thing existed as magnetic conduction. The only magnetic currents we know are magnetic displacement currents and convection currents, such as are used in unipolar and some other dynamos. It is in this difference that we must look for the difference between electricity and magnetism.

In order to observe the existence of these electro-magnetic oscillations we can employ the principle of resonance to generate oscillations in a system whose free period of oscillation is the same. A magnetic receiver may be employed, consisting of a single incomplete circle of wire broken by a very minute spark-gap, across which a spark leaps when the oscillations in the wire become sufficiently intense. In order that a large audience may observe the occurrence of sparks, the terminals of a galvanometer circuit were connected, one with one side of the spark-gap, and the other with a fine point which could be approached very close to the other side of the spark-gap. It was observed that, when a spark occurred in the gap, a spark could also be arranged to occur into the galvanometer circuit, and, with a delicate long-coil galvanometer (that used had 40,000 ohms resistance), a very marked deflection can be produced whenever a spark occurs. This arrangement we have only succeeded in working comparatively close to the generator, because the delicacy required in adjusting the two spark-gaps is so great. It can, however, be employed to show that the sparks produced in this magnetic resonant circuit are due to resonance by removing this receiver from the generator to such a distance that sparks only just occur, and then substituting for the single circuit a double circuit, which, except for resonance, should have a greater action than the single one, but which stops the sparking altogether. An electric receiver was also used, which was identical with the generator, and had a corresponding, only much smaller, spark-gap between the two plates. When the plates are connected with the terminals of the galvanometer, upon the occurrence of each spark the galvanometer is deflected. It is not so easy to obtain sparks when the plates are connected with the galvanometer as when they are insulated, and it is this that has limited the use of this method of observation. By making the first metre or so of the wires to the galvanometer of extremely fine wire, so as to reduce their capacity, we have found that the difficulty of getting sparks is less than with thick wires. We have not observed any effect due to the thickness of the wires after a short distance from the receiver.

In the case of the small oscillator, a receiver exactly like the one described by Prof. Hertz in his second paper already quoted was placed in the focal line of a cylindrical parabolic mirror, and its receiving wires were connected with the wires leading to the galvanometer by some very fine brass wire. With the large-sized generator and receiver, which were placed about 3 metres apart, it was shown that the sparking was stopped by placing a thin zinc sheet so as to reflect the radiations from a point close behind the receiver. By means of a long india-rubber tube hung from the ceiling, it was shown how, when waves are propagated to a point whence they are reflected, the direct and reflected waves interfering produce a system of loops and nodes, with a node at the reflecting point. It was explained that these nodes, though places of zero displacement, were places of maximum rotation, and that the axis of rotation was at right angles to the direction of displacement. It was explained that an analogous state of affairs existed in the electro-magnetic vibrations. If the electric force be taken as analogous to the displacement of the rope, the magnetic may be taken as analogous to its rotation, and the two are at right angles to one another. In the ether the electric node is a magnetic loop, and *vice versâ*. Though the two are separated in loops and nodes, they exist simultaneously in a simple wave propagation, just as in a rope when propagating waves in one direction the crest of maximum displacement is also that of maximum rotation. It was explained that by placing the reflector at a quarter of a wave-length from the receiver this would be at an electric loop, and have its sparking increased. It may thus be shown that there are a series of loops and nodes produced by reflection of these electromagnetic forces, like those produced in any other case of reflected wave-propagation. This was Hertz's fundamental experiment, by which he proved that electro-magnetic actions are propagated in time, and by some approximate calculations he verified Maxwell's theory that the rate of propagation is the same as that of light. It follows that the luminiferous ether is experimentally shown to be the medium to which electric and magnetic actions are due, and that the electro-magnetic waves we have been studying are really only very long light waves.

A rather interesting deduction from Maxwell's theory is that light incident on any body that absorbs or reflects it should press upon it and tend to move it away from the source of light. Illustrating this, an experiment was shown with an alternating current passing through an electro-magnet, in front of which a good conducting plate of silver was suspended. When the alternating current was turned on the silver was repelled. It was explained that as the silver could only be affected by what was going on in its own neighbourhood, and that if sufficiently powerful radiations from a distant source were falling on the silver, it would be acted on by alternating magnetic forces, this experiment was in effect an experiment on the repulsion of light, which was too small to have been yet observed, even in the case of concentrated sunshine. These slow vibrations are not stopped by a sheet of zinc, though much reduced by a magnetic sheet like tin-plate, though the rapid ones are quite stopped by either—thus showing that wave-propagation in a conductor is of the nature of a diffusion.

In all cases of diffusion where we consider the limits of the problem, terms involving the momentum of the parts of the body must be introduced. It appears from elementary theories of diffusion as if it were propagated instantaneously, but no action can be propagated from molecule to molecule, in air, for instance, faster than the molecules move, *i.e.* at a rate comparable with that of sound. In electro-magnetic theory corresponding terms come in by introducing displacement currents in conductors, and it seems impossible but that some such terms should be introduced, as otherwise electro-magnetic action would be propagated instantaneously in conductors. The propagation of light through electrolytes, and the too great transparency of gold leaf, point in the same direction.

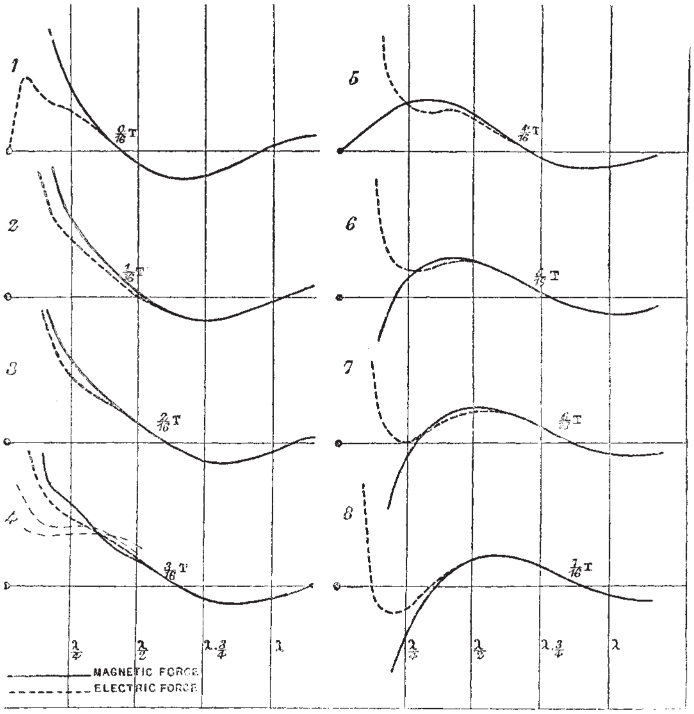
The constitution of these waves was then considered, and it was explained that if magnetic forces are analogous to the rotation of the elements of a wave, then an ordinary solid cannot be analogous to the ether because the latter may have a constant magnetic force existing in it for any length of time, while an elastic solid cannot have continuous rotation of its elements in one direction existing within it. The most satisfactory model, with properties quite analogous to those of the ether, is one consisting of wheels geared with elastic bands. The wheels can rotate continuously in one directionn, and their rotation is the analogue of magnetic force. The elastic bands are stretched by a difference of rotation of the wheels, and introduce stresses quite analogous to electric forces. By making the elastic bands of lines of governor balls, the whole model may have only kinetic energy, and so represent a fundamental theory. Such a model can represent media differing in electric and magnetic inductive capacity. If the elasticity of the bands be less in one region than another, such a region represents a body of higher electric inductive capacity, and waves would be propagated more slowly in it. A region in which the masses of the wheels was large would be one of high magnetic inductive capacity. A region where the bands slipped would be a conducting region. Such a model, unlike most others proposed, illustrates both electric and magnetic forces and their inter-relations, and consequently light propagation.

In the neighbourhood of an electric generator the general distribution of the electric and magnetic forces is easily seen. The electric lines of force must lie in planes passing through the axis of the generator, while the lines of magnetic force lie in circles round this axis and perpendicular to the lines of electric force. It is thus evident that the wave is, at least originally, polarized. To show this, the small-sized oscillators with parabolic mirrors were used, and a light square frame, on which wires parallel to one direction were strung, was interposed between the mirrors. It was shown that such a system of wires was opaque to the radiation when the wires were parallel to the electric force, but was quite transparent when the frame was turned so that the wires were parallel to the magnetic force. It behaved just like a tourmaline to polarized light. It is of great interest to verify experimentally Maxwell's theory that the plane of polarization of light is the plane of the magnetic force. This has been done by Mr. Trouton, who has shown that these radiations are not reflected at the polarizing angle by the surface of a non-conductor, when the plane of the magnetic force in the incident vibration is perpendicular to the plane of incidence, but the radiations are reflected at all angles of incidence when the plane of the magnetic force coincides with the plane of incidence. Thus the long-standing dispute as to the direction of vibration of light in a polarized ray has been at last experimentally determined. The electric and magnetic forces are not simultaneous near the oscillator. The electric force is greatest when the electrification is greatest, and the magnetic force when the current is greatest, which occurs when the electrification is zero: thus the two, when near the oscillator, differ in phase by a quarter of a period. In the waves, as existing far from the oscillator, they are always in the same phase. It is interesting to see how one gains on the other. It may be worth observing, again, that though what follows deals with electric oscillators, the theory of magnetic oscillators is just the same, only that the distribution of magnetic and electric forces must be interchanged. Diagrams drawn from Hertz's figures published in *Wiedemann's Annalen* for January 1889, and in NATURE, vol. xxxix. p. 451, and in the *Philosophical Magazine* for March 1890, were thrown on the screen in succession, and it was pointed out how the electric wave, which might be likened to a diverging whirl ring, was generated, not at the oscillator, but at a point about a quarter of a wave-length on each side of the oscillator, while it was explained that the magnetic force wave starts from the oscillator. It thus appears how one gains the quarter-period on the other. The outflow of the waves was exhibited by causing the images to succeed one another rapidly by means of a zoëtrope, in which all the light is used and the succession of images formed by having a separate lens for each picture and rotating the beam of light so as to illuminate the pictures in rapid succession.

As the direction of flow of energy in an electro-magnetic field depends on the directions of electric and magnetic force, being reversed when either of these is reversed, it follows that in the neighbourhood of the oscillator the energy of the field alternates between the electric and magnetic forms, and that it is only the energy beyond about a quarter of the wave-length from the oscilllator which is wholly radiated away during each vibration. It follows that in ordinary electro-magnetic alternating currents at from 100 to 200 alternations per second, it is only the energy which is some 3000 miles away which is lost. If an electro-magnetic wave, having magnetic force comparable to that near an ordinary electro-magnet, were producible, the power of the radiation would be stupendous. If we consider the possible radiating power of an atom by calculating it upon the hypothesis that the atomic charge oscillates across the diameter of the atom, we find that it may be millions of millions of times as great as Prof. Wiedemann has found to be the radiating power of a sodium atom in a Bunsen burner, so that, if there is reason to think that any greater oscillation might disintegrate the atom, it is evident that we are still a long way from doing so. It is to be observed that ordinary light-waves are very much longer than the period of the vibration above referred to. Dr. Lodge has pointed out that quite large oscillators in comparison to molecules—namely, about the size of the rods and cones in the retina—are of the size to resound to light-waves of the length we see, and so might be used to generate such waves. This seems to show that the electro-magnetic structure of an atom must be more complicated than a small sphere or other simple shape with an oscillating charge on it, for the period of vibration of a small system can be made long by making the system complex, *e.g.* a small Leyden jar of large capacity with a long wire wound many times round connecting its coats, could easily be constructed to produce electro-magnetic waves whose length would bear the same proportion to the size of the jar as ordinary light-waves do to an atom. The rate at which the energy of a Hertzian vibrator is transferred to the ether is so great that we would expect an atom to possess the great radiating power it has. This shows, on the other hand, how completely the vibrations of an atom must be forced by the vibrations of the ether in its neighbourhood, so that atoms, being close compared with a wave-length, are, in any given small space, probably in similar phases of vibration. It is interesting to consider this in connection with the action of molecules in collision as to how far the forces between molecules after collision is the same as before. In the same connection the existence of intra-atomic electro-magnetic oscillations is interesting in the theories of anomalous dispersion. An electro-magnetic model of a prism with anomalous dispersion might be constructed out of pitch, through which conductors, each with the same rate of electro-magnetic oscillation, were dispersed. In theories of dispersion a dissipation of energy is assumed, and it may be the radiation of the induced electro-magnetic vibrations. These can evidently never be greater than the incident electro-magnetic vibration, on account of this radiation of their own energy. In some theories a vibration of something much less than the whole molecule is assumed, and the possibility of intra-atomic electro-magnetic oscillations would account for this. Some such assumption seems also required, in order to explain such secondary, if not tertiary, actions as the Hall effect and the rotation of the plane of polarization of light, which are, apparently at least, secondary actions due to a reaction of the matter set in motion by the radiation on this radiation.

Some further diagrams were exhibited, plotted from Hertz's theory by Mr. Trouton, to whom much of the matter in this paper is due. They are here reproduced, and show eight simultaneous positions of the electric and magnetic waves during a semi-oscillation of an electric oscillator. The dotted line shows the electric force at various points, and the continuous line the magnetic force. In the first diagram the magnetic force is at its maximum near the origin, while the electric force there is zero. In the second the magnetic energy near the origin has partly turned into electric energy, and consequently electric force begins. The succeeding figures show how the magnetic force decreases near the origin, while the electric force grows, and the waves already thrown off spread away. The change of magnetic force between Figs. 4 and 5 is so rapid, that a few dashed lines, showing interpolated positions, are introduced to show how it proceeds. It will be observed how a hollow comes in the line showing electric force, which gradually increases, and, crossing the line of zero force at about a quarter of a wave-length from the origin, is the source of the electric wave, which, starting with this odds, picks up and remains thenceforward coincident with the magnetic wave. From this origin of electric waves they spread out along with the magnetic waves and in towards the origin, to be reproduced again from this point on the next vibration. These electric and magnetic forces here shown as coincident are, of course, in space in directions at right angles to one another, as already explained. The corresponding diagrams for a magnetic oscillator are got by interchanging the electric and magnetic forces.

A further experiment was shown to illustrate how waves of transverse vibration can be propagated along a straight hollow vortex in water. It was stated that what seemed a possible theory of ether and matter was that space was full of such infinite vortices in every direction, and that among them closed vortex rings represented matter threading its way through the ether. This hypothesis explains the differences in Nature as differences of motion. If it be true, ether, matter, gold, air, wood, brains, are but different motions. Where alone we can know what motion in itself is—that is, in our own brains—we *know* nothing but thought. Can we resist the conclusion that all motion is thought? Not that contradiction in terms, unconscious thought, but living thought; that all Nature is the language of One in whom we live, and move, and have our being.



THE CLIMATES OF PAST AGES.[1]

II.

We need not enter on a detailed description of the other vegetable types of the Coal-measure formation; we can only note the abundant occurrence of tree-ferns, and the existence of not very numerous conifers, which amid this strange vegetation are the forms most nearly related to those of our present world.

The geographical extent of this typical flora was extraordinarily great; we trace it from the shores of the Atlantic through the northern half of the Old World to China, and it is also greatly developed in the eastern half of the United States. There, and in China, are the greatest developments of beds of coal. Besides these, we find similar deposits with nearly the same vegetation in the far north, in the American polar archipelago, in Spitzbergen, and Nova Zembla. It is these facts that have led to the conclusion, already mentioned, that in the Carboniferous period a uniform climate prevailed from the equator to the pole, together with a dense atmosphere rich in carbon-dioxide, and impenetrable to the solar rays. And yet a simple examination of the facts assures us that all these suppositions are groundless. In so far as regards the character of the flora, we really know nothing of the temperature requisite to the Calamites, Lepidodendra,

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[1] Translation of a Lecture delivered by the late Dr. M. Neumayr before the Society for the Dissemination of Natural Science, at Vienna, on January 2, 1889. Continued from p. 151.